TECHNICAL NOTE
D-251

A SUMMARY OF OPERATING CONDITIONS EXPERIENCED BY TWO HELICOPTERS IN A COMMERCIAL AND A MILITARY OPERATION

By Andrew B. Connor and LeRoy H. Ludi

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON April 1960

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL NOTE D-251

A SUMMARY OF OPERATING CONDITIONS EXPERIENCED BY TWO HELICOPTERS IN A COMMERCIAL AND A MILITARY OPERATION

By Andrew B. Connor and LeRoy H. Ludi

L
8
3
5

SUMMARY

A survey is presented of the conditions under which a helicopter engaged in commercial operations and a helicopter engaged in military operations were operated. The data, obtained with an NASA (formerly NACA) helicopter VGHN recorder, represent 2,366 flights or 410 flying hours.

The results indicate that neither helicopter was operated above the maximum allowable airspeed and both helicopters spent the largest percentage of time at approximately 60 to 70 percent of the maximum design airspeed. The rates of climb and descent were varied and distributed over the entire airspeed range for both helicopters. During this survey, both helicopters made approximately 6 landings per flying hour. Both helicopters were operated at normal rotor rotational speeds during all flight conditions.

The center-of-gravity normal acceleration experience above a threshold of ±0.4g was more severe in the military operation than in the air-mail operation.

INTRODUCTION

Design and service life criteria for helicopters are based on the expected stress history as determined by the flight time in various flight conditions and the frequency of the stress levels encountered in the flight conditions. A limited amount of information on the time spent in the flight conditions of climb, en route, and descent, based on actual operating experience of various helicopters in the performance of their missions, is presented in references 1 and 2. Rotor-blade bending moments in various conditions, as measured in flight, are given in references 3 to 5. The continuous study of operating experience obtained from various helicopter missions will enable the designer to provide the user with an aircraft more suitable to his needs.

This report covers the operations survey of an airmail helicopter in the Los Angeles area and a military helicopter at Ft. Bragg, North Carolina. The airmail helicopter, a single rotor configuration, was engaged in both airmail and passenger service. According to references 1 and 2, a helicopter airmail operation, by nature, is highly repetitive in flight profile experience. Because of this constancy of operation, the distribution of the many slight deviations which arise from one flight profile to another can be obtained by sampling a large quantity of records. The military helicopter, a tandem rotor configuration, was engaged in a tactical support evaluation test simulating field support missions. The military operation having varied flight profiles and a smaller quantity of records for analysis provides distributions that would be generally less indicative of the actual total experience than would be derived from a large quantity of records as in an airmail operation. The purpose of this paper is to present more extensive information on the time spent within these classifiable flight conditions and to provide this information with respect to two helicopter types and missions.

HELICOPTER OPERATIONS

The airmail operations data for this study were obtained from the same organization, in the Los Angeles area, that cooperated in providing the data for reference 1. This survey was conducted approximately 3 years after the survey reported in reference 1; a different type of helicopter was used; and passenger service was added to the airmail service. The helicopter in this case has an approximate gross weight of 6,700 pounds. The operation was surveyed over a 10-month period during which time 320 flying hours were recorded from 1,880 flights. The flights ranged in duration from 1 minute to 34 minutes.

The military operation was a tactical evaluation of a tandem rotor helicopter that had a gross weight on the order of 5,500 pounds. This helicopter had already been accepted into the service and the test was to determine its most effective utilization in tactical support operations. Four hundred and eighty six (486) flights or approximately 90 flying hours were recorded. The flights ranged in duration from 3 to 33 minutes.

INSTRUMENTATION AND DATA EVALUATION

The data for these surveys were obtained by use of an NASA (formerly NACA) helicopter VGHN recorder which recorded time histories of airspeed, center-of-gravity normal acceleration, pressure altitude, and rotor rotational speed. Before the instrument was modified to record rotor rotational speed, it was the same type as that described in reference 6.

The flight-profile data were evaluated by taking a 10-percent sampling of the total quantity of flight records. The normal-acceleration experience data were evaluated by reading the total quantity of the flight records.

RESULTS AND DISCUSSION

The results are presented as a breakdown of operating experience according to time spent within classifiable flight conditions for the scheduled airmail and military missions.

Operating Airspeed

The percent of time spent at various airspeeds for both the airmail and military operations is presented in figure 1. In this figure the percentage of total time in certain airspeed brackets is plotted against the percent of maximum design airspeed for each helicopter. The maximum airspeed, as determined from the pilot's handbook, is 115 knots for the airmail helicopter and 100 knots for the military helicopter. The total airspeed experience is presented in figure 1(a). Figure 1(b) presents the airspeed experience as it was accumulated in the flight conditions of climb, en route, and descent.

The airspeed experience of the two helicopters was grouped in increments of 20 knots, but for the airmail helicopter the total time spent in the 0- to 20-knot range was not significantly different from the total time spent in the 20- to 40-knot range. Furthermore, the airspeed recorder is quite insensitive in the 0- to 20-knot range; thus, separation in that range has a greater likelihood for error. As a result of the airmail operation analysis the military operation was therefore surveyed for a low-speed range extending from 0 to 40 knots.

Since the maximum airspeed is often determined by retreating-blade stall rather than by the power required, the time spent at or above the maximum airspeed would indicate operations in a condition of increased rotor blade moments as shown in reference 4. An inspection of figure 1(a) shows that neither helicopter was operated above the maximum airspeed during this survey.

Another airspeed range that may be even more significant to the helicopter designer is the range from 0 to 40 percent of the maximum airspeed. Reference 5 shows that in this range the vibratory moments during transition and landing approaches become very large. Figure 1(a) shows that the airmail helicopter operated in the low-speed range only 3 percent of the time; the military helicopter operated in this range over 14 percent of the time.

Figure 1(a) also shows that the airmail helicopter spent more than 65 percent of the total time in flight at approximately 60 percent of the maximum airspeed; whereas the military helicopter spent more than 54 percent of the total time at about 70 percent of the maximum airspeed.

Reference 3 notes that increased stress levels occur in maneuvering flight and that the significant maneuvers in airmail and tactical cargo operations are those which occur during climb and descent. Figure 1(b) shows the percent of total time spent in those flight conditions based on the V_{max} of each helicopter. Time spent in climb at the low-speed range, up to about 40 percent V_{max}, was about 7 percent for the military and about 2 percent for the airmail helicopter. In both operations the time spent in descent in the airspeed range up to about 40 percent V_{max} was approximately 5 percent of the total time. Figure 1(b) also shows the percent of total time spent en route in order that the low to moderate periodic bending moments experienced during a large number of cycles might be correctly weighted. Both helicopters were operated more than 50 percent of the time en route at approximately 60 to 65 percent V_{max}.

L
8
3
5

In the airmail operation reported in this paper, in spite of a time lapse of about 3 years and changes in route and helicopter type, the time spent at all airspeeds per flight condition was in reasonably close agreement with the airmail operation reported in reference 1. Modernization of equipment and technique, revisions in operating procedure, and climate and terrain conditions are all features which contribute to the flight profile of a helicopter engaged in a specific type mission. However, the airmail operation reported in reference 2 also agrees fairly well in the time spent per flight condition experience. The "time-spent" experience of the three airmail operations and the military operation is summarized in table I. In general, the range of total times spent within the flight conditions is very narrow. Time in climb ranged from 14 to 17 percent, time en route ranged from 71 to 77 percent, and time in descent ranged from 9 to 12 percent among the four operations surveyed.

Operating Rates of Climb and Descent

The percent of time spent at the various rates of climb and descent for both the airmail and military operations is presented in figure 2. In this figure the percent of time in climb or descent, based on the total time in each condition, is plotted against the rate of climb or descent in the various airspeed brackets. The rates of change in altitude were taken to the nearest 100 feet per minute.

The rates of climb for the airmail helicopter are shown in figure 2(a). The figure shows that the rate of climb varied from 200 feet per minute to 1,000 feet per minute. It also shows that the airmail helicopter spent the largest percentage of time in climb at a rate of 600 to 800 feet per minute in the 40- to 60-knot airspeed bracket. The next largest percentage of time was spent climbing at a rate of 500 to 800 feet per minute in the 60- to 80-knot airspeed bracket. The percentage of time does not exceed 2 percent in the lower speed ranges and lower rates of climb.

The rates of climb for the military helicopter are shown in figure 2(b). The figure shows that the rates of climb varied from 200 feet per minute to 1,800 feet per minute and were mostly distributed in the 0- to 60-knot airspeed range. The largest percentage of time was spent climbing at a rate of 600 feet per minute in the 0- to 40-knot airspeed range.

A comparison of the rate-of-climb distribution of the two operations (figs. 2(a) and 2(b)) shows that the airmail helicopter was operated more consistently within a narrower range of climb-out rates and airspeeds than the military helicopter.

The rates of descent for the airmail helicopter are shown in figure 2(c). The figure shows that the descent rate varied from 200 feet per minute to 1,600 feet per minute and was distributed in all airspeed categories. In the 0- to 40-knot airspeed bracket, the percentage of time spent at any rate of descent never exceeded 2 percent. In the 40- to 100-knot range, the percentage of time at any rate of descent never exceeded 6 percent.

The military helicopter operating rates of descent are shown in figure 2(d). The figure shows that the rate of descent varied from 200 feet per minute to 3,000 feet per minute, most of the time being spent at descent rates of 1,600 feet per minute or less. The fact that the military helicopter spent approximately 5 percent of the time at a rate of descent of 3,000 feet per minute indicates that autorotational type of descents were being utilized for the performance of the mission.

A comparison of the rate-of-descent distribution of the two operations (figs. 2(c) and 2(d)) shows that there was no consistent choice in the airspeed or rate of descent in either operation.

The analysis of the rates of climb and descent with airspeed shows the conditions of horizontal- and vertical-velocity experience since the flow pattern varies in climb and descent according to these two components. Furthermore, adverse flow patterns might result in increased stresses that are not ordinarily taken into account. Prototype testing, for example, may show interference effects in a tandem rotor at some particular combination of indicated airspeed and rate of change in altitude. In this regard, the airmail helicopter experience, although obtained with a single rotor configuration, may be as useful as tandem rotor experience in that the designer could allow for the operator's preferred flight profile and possibly minimize operating limitations that might otherwise be encountered.

The number of landings per flying hour may also be significant to the designer since each of these represents a transition and flare. The airmail helicopter made 1,880 flights in 320 hours for a total of 5.9 landings per flying hour; and the military helicopter made 486 flights in 90 hours for a total of 5.4 landings per flying hour.

L
8
3
5

Operating Rotor Rotational Speed

The two operations in this report are the first in which operating rotor rotational speed was surveyed with the NASA helicopter VGHN recorder. The percent of time spent at the various rotor rotational speeds for both the airmail and military operations is presented in figure 3. In this figure the time spent at various rotational speeds as a percent of total time is plotted against the ratio of flight operating rotor rotational speed to maximum power rotor rotational speed. The percent of the total flight time spent at the various speed ratios during climb, en route, and descent is also shown. Figure 3 shows that the operators maintained a fairly constant rotor rotational speed near the maximum power speed during all flight conditions and that variations are slight. The rotor was operated within ±0.05 of the normalized value during 95 percent of the time in flight. Only in the descent condition, where autorotation with its higher maximum design speed is possible, is there any widespread variation in rotor rotational speed. The operating rotor rotational speed is of interest to the designer since the maximum predictable load factor in a given configuration is a function of rotor speed squared, when all blade sections are assumed to be operating at maximum lift coefficient as shown in reference 7.

Center-of-Gravity Normal Acceleration

An analysis of the normal-acceleration experience of the airmail helicopter was made in a manner similar to that reported in references 1 and 2. The results were practically identical. A similar treatment was also made of the military helicopter with no apparent variations in experience up to incremental accelerations of ±0.5g. At values greater than ±0.5g, the experience became more varied.

As a result of this analysis and information obtained from references 1 and 2, the normal accelerations within a band of ±0.4g from the 1.0g flight condition were considered ordinary and sufficiently treated. All the acceleration increments greater than ±0.4g were counted and tabulated by magnitude in table II according to the flight conditions of climb, en route, and descent. The greatest number of the larger normal acceleration increments were negative and occurred at the initiation of descent. Time spent during the accelerated condition generally ranged from 2 to 3 seconds, but in two instances the time deviation was approximately 8 seconds from the beginning of the acceleration until return to the 1.0g flight condition.

Examination of the number of center-of-gravity normal accelerations per flight hour, as shown in table II, indicates that the loads experience of the military operation was much more severe than that of the airmail operation. If the descent condition alone is considered, the military helicopter experienced 9.5 accelerations per hour that were greater than ±0.4g, compared with the airmail helicopter which experienced 1.5 per hour.

CONCLUDING REMARKS

A survey has been made of the conditions under which a single rotor helicopter engaged in airmail and passenger operations and a tandem rotor helicopter participating in a military tactical evaluation were operated.

The results show that neither helicopter was operated above the maximum design airspeed during this survey. In addition, both helicopters spent the largest percentage of the total time at airspeeds of approximately 60 to 70 percent of the maximum design airspeed.

The rates of climb and descent at which the two helicopters operated were varied and distributed over the entire airspeed range but the airmail helicopter was more consistent during climb than the military helicopter. During this survey, both helicopters made approximately 6 landings per flying hour.

The results also show that both helicopters were operated at normal rotor rotational speeds during all flight conditions.

The center-of-gravity normal acceleration experience above a threshold of ±0.4g was more severe in the military operation than the airmail operation. During the descent condition the military helicopter experienced 9.5 accelerations per hour compared with 1.5 per hour in the airmail helicopter.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 8, 1960.

REFERENCES

1. Crim, Almer D., and Hazen, Marlin E.: Normal Accelerations and Operating Conditions Encountered by a Helicopter in Air-Mail Operations. NACA TN 2714, 1952.

2. Hazen, Marlin E.: A Study of Normal Accelerations and Operating Conditions Experienced by Helicopters in Commercial and Military Operations. NACA TN 3434, 1955.

3. Ludi, LeRoy H.: Flight Investigation of Effects of Atmospheric Turbulence and Moderate Maneuvers on Bending and Torsional Moments Encountered by a Helicopter Rotor Blade. NACA TN 4203, 1958.

4. Ludi, LeRoy H.: Flight Investigation of Effects of Retreating-Blade Stall on Bending and Torsional Moments Encountered by a Helicopter Rotor Blade. NACA TN 4254, 1958.

5. Ludi, LeRoy H.: Flight Investigation of Effects of Transition, Landing Approaches, Partial-Power Vertical Descents, and Droop-Stop Pounding on the Bending and Torsional Moments Encountered by a Helicopter Rotor Blade. NASA MEMO 5-7-59L, 1959.

6. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

7. Gustafson, F. B., and Crim, Almer D.: Flight Measurements and Analysis of Helicopter Normal Load Factors in Maneuvers. NACA TN 2990, 1953.

TABLE I.- SUMMARY OF FLIGHT PROFILE EXPERIENCE OF

FOUR DIFFERENT HELICOPTERS

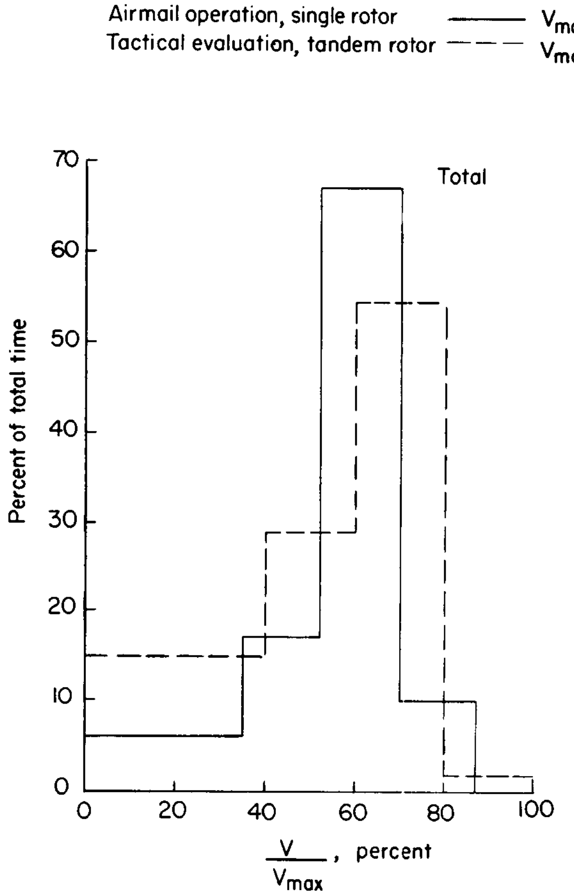
Type of helicopter	Type of operation	Percent of flight time in indicated flight condition		
		Climb	En route (a)	Descent
6,700-pound single rotor	Airmail	17.0	71.0	12.0
5,500-pound tandem rotor	Military	13.5	75.7	10.8
5,000-pound single rotor (ref. 1)	Airmail	14.5	73.8	11.7
2,300-pound single rotor (ref. 2)	Airmail	14.0	77.0	9.0

[a]En route is defined as the flight condition where changes in altitude are less than ±300 feet per minute.

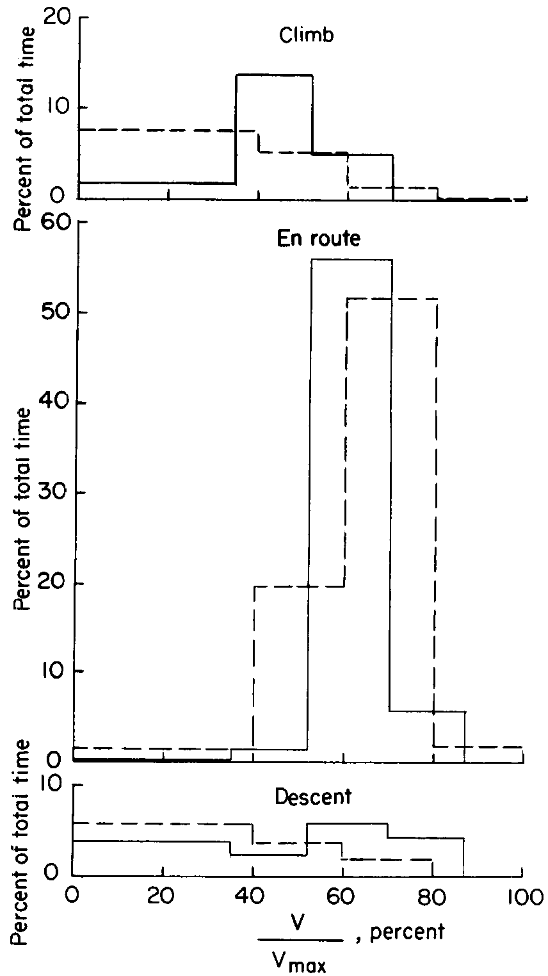
TABLE II.- NORMAL ACCELERATION EXPERIENCE OF BOTH OPERATIONS INCLUDING ALL INCREMENTS ABOVE A THRESHOLD OF ±0.4g

Acceleration increment, Δa_n, g units	Airmail			Military		
	Climb	En route	Descent	Climb	En route	Descent
0.45	2		6			4
.50	1	3	3	1		1
.55			2		1	4
.60			1	2		6
.65	1		2		1	2
.70			1	1	2	2
.75			1	1		
.80				1		2
.85					1	
Total	4	3	16	6	5	21
-0.45						1
-.50	2	8	16		2	9
-.55	1	2	11		2	14
-.60	1	3	6		2	12
-.65		1	7	2		7
-.70		2	2		3	15
-.75						10
-.80						3
-.85	1				1	
-1.00			1			
Total	5	16	43	2	10	71
Flight hours per condition	54.5	227	38.5	12.1	68.2	9.7

L
8
3
5

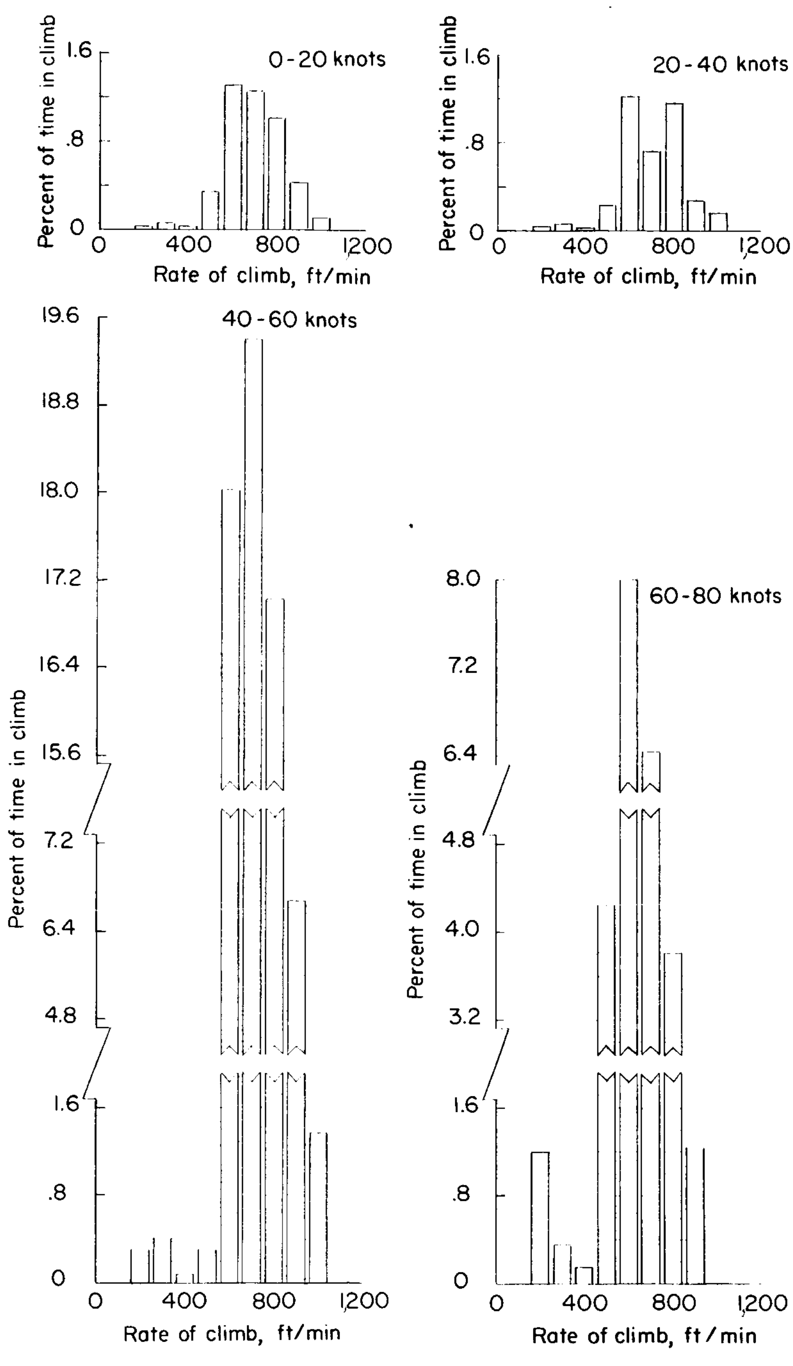


(a) Total airspeed experience.



(b) Airspeed experience according to the flight condition of climb, en route, and descent.

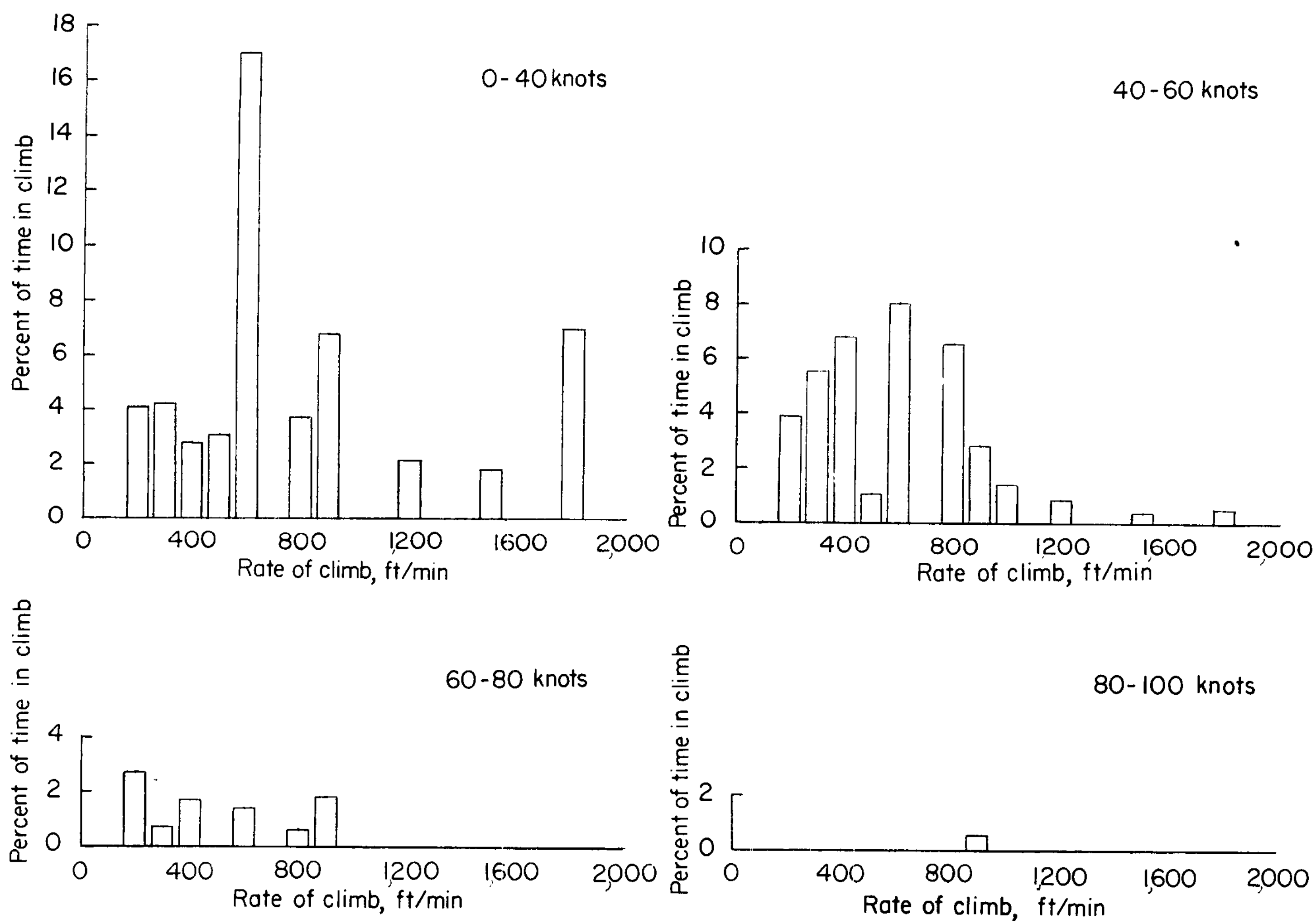
Figure 1.- Operating airspeed experience for an airmail and a military helicopter.



(a) Rates of climb; airmail.

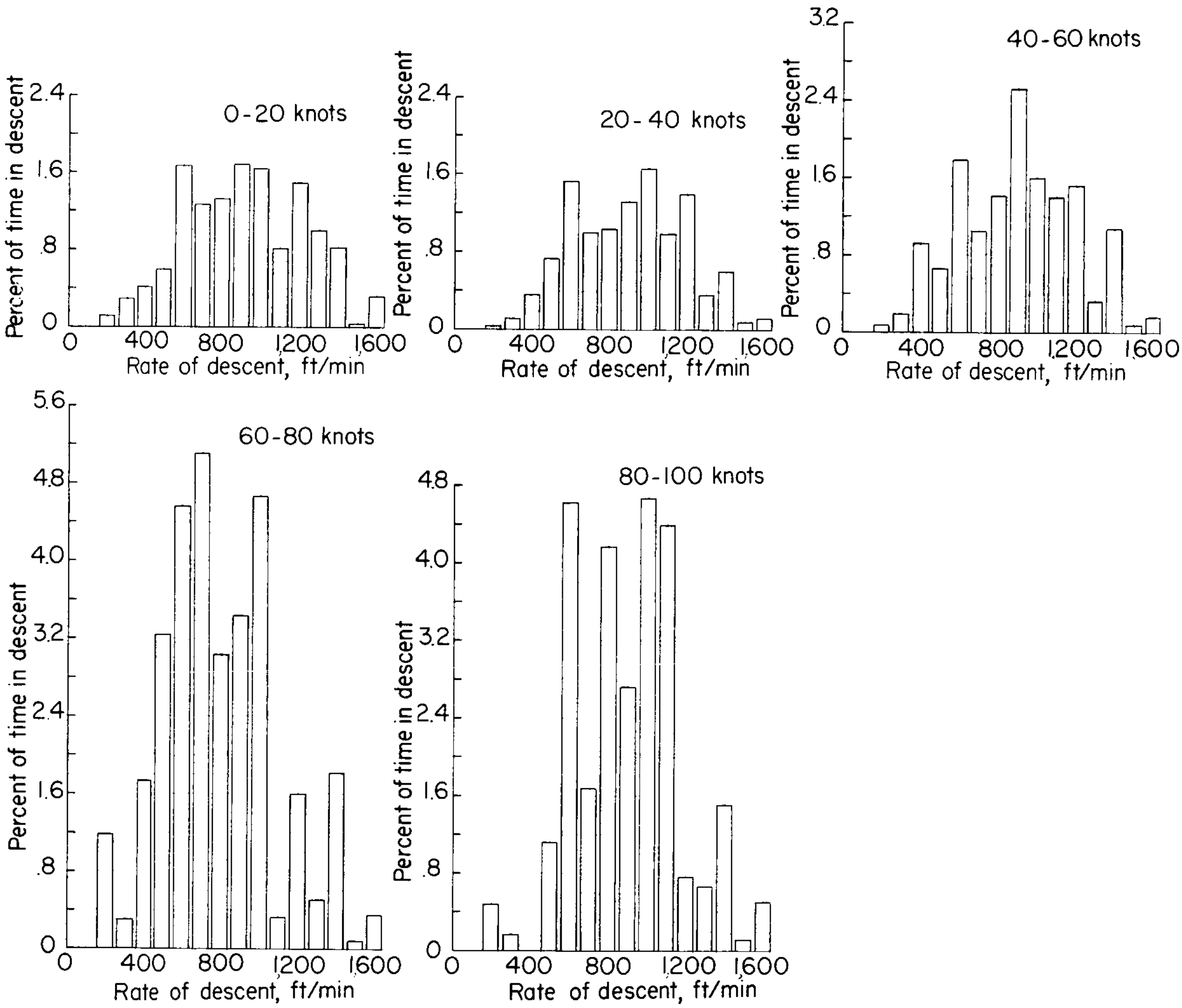
Figure 2.- Operating rates of climb and descent experience for an airmail and a military helicopter.

L-835



(b) Rates of climb; military.

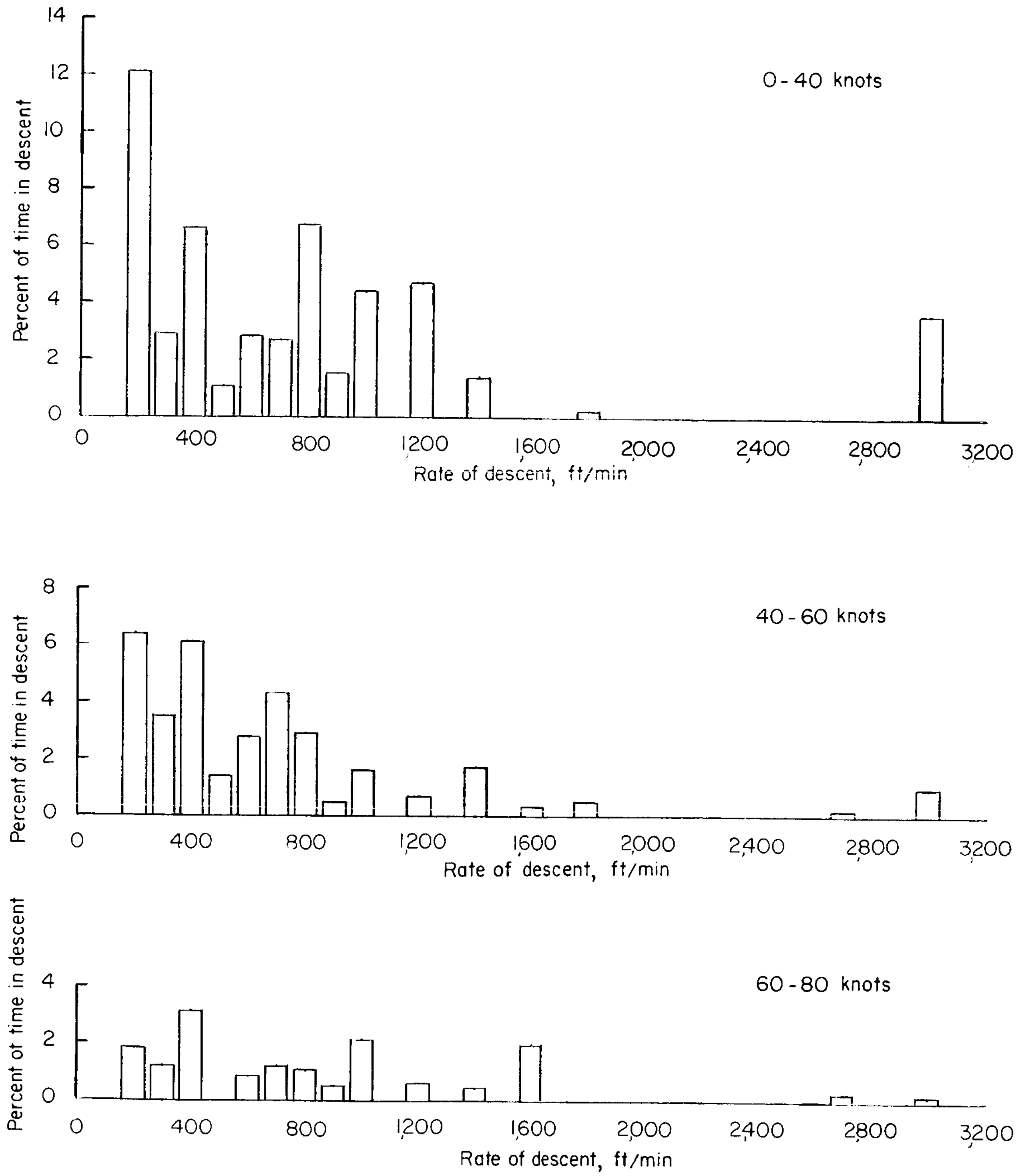
Figure 2.- Continued.



(c) Rates of descent; airmail.

Figure 2.- Continued.

L-835



(d) Rates of descent; military.

Figure 2.- Concluded.

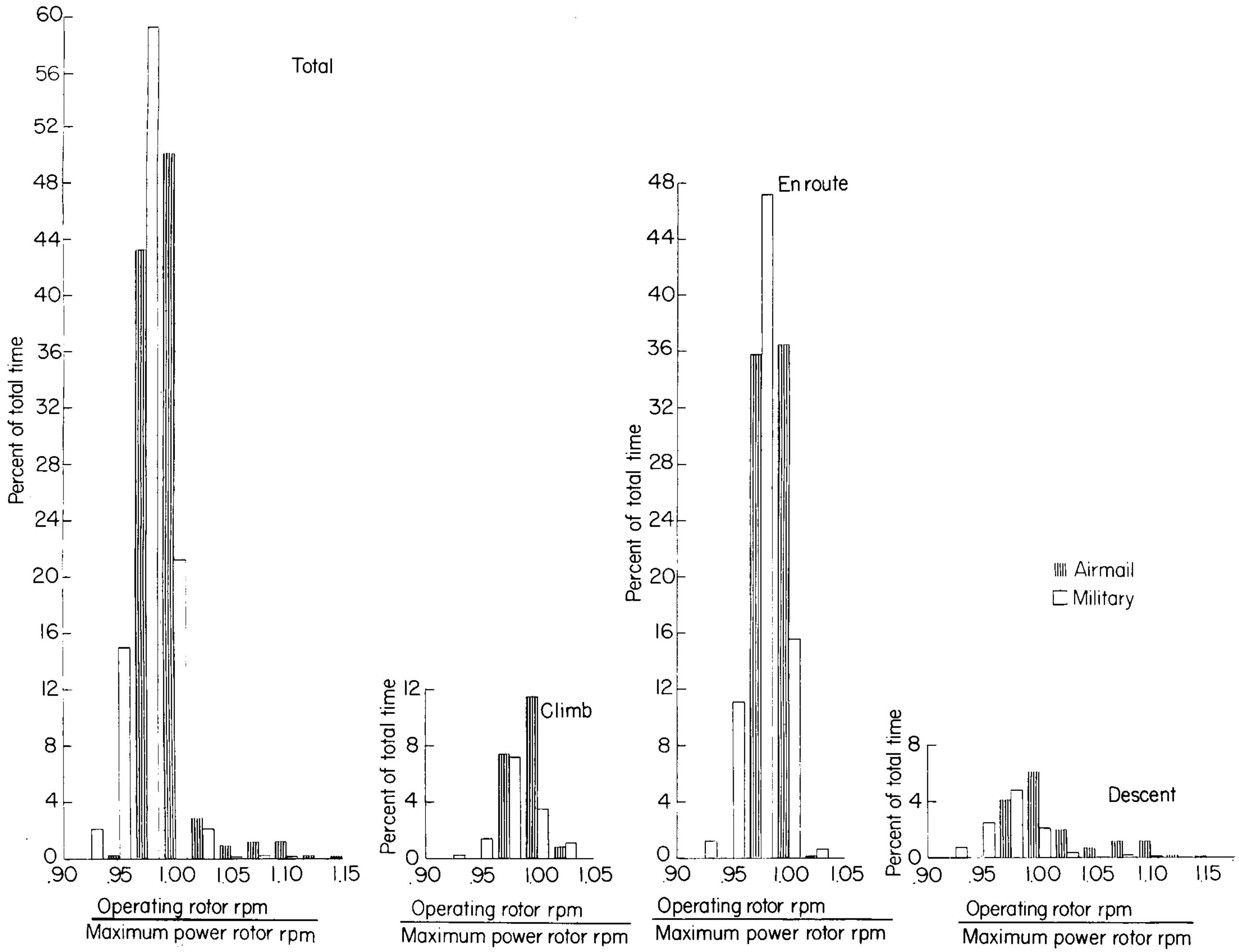


Figure 3.- Operating rotor rotational speed experience for an airmail and a military helicopter.